AD-A267 602

NASA/DoD Aerospace Knowledge Diffusion Research Project

NASA Technical Memorandum 107673

Report Number 14

Engineering Work and Information Use in Aerospace: Results of a Telephone Survey

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93-17929

October 1992

National Aeronautics and Space Administration

Department of Defense

INDIANA UNIVERSITY

93 8 4 208

INTRODUCTION

Engineers are an extraordinarily diverse group of professionals, but an attribute common to all engineers is their use of information. Mailloux highlights the centrality of information to engineering. She reports that about "20 percent of an engineer's time is spent in the intellectual activities of engineering -- conceiving, sketching, calculating, and evaluating -- with the remaining 80 percent spent on activities associated with creating, accessing, receiving, manipulating, or transferring information" (239). Considering the relationship between engineering work and the use of information, surprisingly little is known about engineers and their information-seeking behavior. The literature regarding the information-seeking behavior of engineers is fragmented and superficial. The results of engineering information studies have not accumulated to form a significant body of knowledge that can be used to develop and design information policy and systems (Rhode 50).

BACKGROUND

The production, transfer, and use of scientific and technical information (STI) are essential parts of aerospace research and development (R&D). For purposes of this discussion, we define STI production, transfer, and use as *Aerospace Knowledge Diffusion*. Studies indicate that timely access to STI can increase productivity and innovation and help aerospace engineers and scientists maintain and improve their professional skills. These same studies demonstrate, however, how little is known about aerospace knowledge diffusion or about how aerospace engineers and scientists find and use STI. To learn more about this process, a research project has been organized to study aerospace knowledge diffusion. This research project is the *NASA/DoD Aerospace Knowledge Diffusion Research Project*.

This research is being undertaken by researchers at the NASA Langley Research Center (LaRC), the Indiana University Center for Survey Research, and Rensselaer Polytechnic Institute (RPI). Several aerospace professional societies have endorsed this

investigation, including the American Institute of Aeronautics and Astronautics (AIAA), and the Advisory Group for Aerospace Research and Development (AGARD), Technical Information Panel (TIP) has sanctioned it. This 4-phase project is providing descriptive and analytical data regarding the diffusion of aerospace knowledge at the individual, organizational, national, and international levels. It is examining both the channels used to communicate and the social system of the aerospace knowledge diffusion process. The *NASA/DoD Aerospace Knowledge Diffusion Research Project* fact sheet appears in Appendix A.

Phase 1 investigates the information-seeking behavior of U.S. aerospace engineers and scientists and places particular emphasis on their use of federally funded aerospace R&D and U.S. government technical reports. Phase 2 examines the industry-government interface and emphasizes the role of information intermediaries in the aerospace knowledge diffusion process. Phase 3 concerns the academic-government interface and focuses on the relationships between and among the information intermediary, faculty, and students. Phase 4 explores patterns of technical communications among non-U.S. aerospace engineers and scientists in selected countries (Pinelli, Kennedy, and Barclay). A list of *NASA/DoD Aerospace Knowledge Diffusion Research Project* publications appears in Appendix B.

METHODOLOGY AND DESIGN

The research reported herein, conducted as a Phase 1 activity, was performed by the Indiana University Center for Survey Research. It was undertaken to obtain information on the daily work activities of aerospace engineers and scientists, to measure various practices used by aerospace engineers and scientists to obtain STI, and to ask aerospace engineers and scientists about their use of electronic networks. Data were collected using a telephone survey between August 14–26, 1991, using the University of California Computer Assisted Survey Methods Software. The Aerospace Division of the Society of Automotive Engineers (SAE) served as the study population. The SAE was selected as the

study population in an attempt to ensure representation of those U.S. aerospace engineers and scientists performing professional duties in design, development, manufacturing, and production.

A diskette supplying the sample frame list was provided by the SAE. Readers should note that the sample included the names of U.S. aerospace engineers and scientists who were on the SAE mailing list, not necessarily members of the SAE. A total of 2,000 names was included on the diskette; however, some names were deleted from the sample frame because the corresponding telephone numbers were not listed. The sample frame was separated according to time zone. The telephone numbers were reviewed to determine whether they were business or home numbers. Only those individuals who provided a home phone number were selected for the sample. Telephone calls were made only on evenings and weekends (unless otherwise requested by the respondent) to minimize the possibility of calling work places.

The questionnaire used in the SAE telephone survey was jointly prepared by the Project team and representatives from the Indiana University Center for Survey Research. The survey was pretested on August 7, 8, and 12, 1991. After the survey was pretested, minor changes were made in wording to improve the flow of the instrument and the quality of the data collected. A pretest letter was sent to those selected to participate in the survey. Data collection began on August 14, 1991, and ended on August 26, 1991. The average length of the interviews was 15 minutes. After completion, each of the 430 completed questionnaires was analyzed. The adjusted completion rate for the survey was 75 percent. The survey instrument appears in Appendix C.

RELATED LITERATURE AND RESEARCH

Recent interest in the information-seeking behavior of engineers corresponds to rising interest and concerns regarding industrial competitiveness and technological innovation. Consequently, an understanding of the information-seeking behavior of engineers is essential to predicting information use and to planning, developing, and implement-

ing engineering information systems. Such an understanding is also critical to enhancing economic competitiveness, improving productivity, and maximizing the process of technological innovation. Relevant literature is presented for the following five topics: the world of engineering, engineering work, engineering knowledge, computer use in engineering, and computer use in aerospace.

The World of Engineering

According to the U.S. Bureau of Labor Statistics, engineers held almost 1,411,000 jobs in 1988 (U.S. Department of Labor). About half of these jobs were located in manufacturing industries; about 511,000 were located in non-manufacturing industries; and about 185,000 were located by federal, state, and local governments. About one-third of these jobs (439,000) were held by electrical engineers followed, in decreasing order of frequency, by mechanical (225,000), civil (186,000), and industrial (132,000) engineers. A bachelor's degree in engineering from an accredited engineering program is generally acceptable for beginning engineering jobs. Most engineering degrees are granted in branches such as electrical, chemical, or nuclear engineering. Most engineers specialize within these branches; professional societies recognize more than 25 major specialties. The Occupational Outlook Handbook (U.S. Department of Labor) lists and discusses the following 10 branches of engineering: aerospace, chemical, civil, electrical and electronics, industrial, mechanical, metallurgical, ceramic and materials, mining, nuclear, and petroleum. Formal registration is a requirement in the U.S. for engineers whose work may affect life, health, or property, or who offer their services to the public. Registration generally requires, in addition to a degree from an engineering program accredited by the Accreditation Board for Engineering and Technology (ABET), four years of relevant work experience and satisfactory performance on a state examination.

Engineering Work

What is engineering work like? What tasks and activities are performed by engineers on a day-to-day basis? Florman, an engineer who has written extensively on the nature of the profession, indicates that "the essence of engineering lies in its need and willingness to embrace opposites. Empiricism and theory, craftsmanship and science, workshop and laboratory, apprenticeship and formal schooling, private initiative, and government venture, commerce and independent professionalism, military necessity and civic benefit -- all of these and more have their place" (64). In trying to sort out the diversity of engineering, Adams notes that it may be categorized according to particular industries, fields, disciplines, job functions, and end products, among other things. He concludes that engineering is interlocked with science, mathematics, and business in a complex environment that "requires a multidimensional map for understanding" (38).

The characteristic activity of engineers is making things. Expressed more formally, engineering is usually defined as the application of scientific knowledge to the creation or improvement of technology for human use (Kemper 3). The term "technology" as used in the context of describing engineering work encompasses products, systems, structures, and processes. Engineering work is often described as a process that originates with the first idea for a new or improved technology that is put into use. The National Research Council, for example, describes what it calls "the product realization process" as extending "over all phases of product development from initial planning to customer follow-up" (1991, 17). Phases in this process include defining customer needs and product performance requirements, planning for product evolution, planning for design and manufacturing, product design, manufacturing process design, and production.

Engineering work can also be described in terms of the kinds of tasks and activities that engineers perform on a day-to-day basis. Because of the multidimensional nature of engineering work and the extensiveness of the product development process, engineers perform a wide variety of tasks. Engineering work involves cognitive activities and physical

tasks that include the technical and the non-technical, the routine and the creative, the rational and the serendipitous. According to Ritti, engineering work consists of scientific experimentation, mathematical analysis, design and drafting, building and testing of prototypes, technical writing, marketing, and project management. Murotake calls attention to the non-technical elements of engineering work: "the process of engineering work is not only a technical one, but a social one in which management, communication, and motivation influence the efficiency, quality, and innovativeness of the project team's work" (20). If the characteristic physical activity of engineering is making things, the characteristic cognitive activity is problem-solving. Laudan notes that "change and progress in technology is achieved by the selection and solution of technological problems, followed by choice between rival solutions" (84).

The great variety in the nature of the tasks and activities that compromise engineering work is often reflected in the individual engineer's work, as well. Kemper notes that the typical engineer is likely to define problems, come up with new ideas, produce designs, solve problems, manage the work of others, produce reports, perform calculations, and conduct experiments (2). Hollister also describes the work of an engineer as multi-faceted: "He begins with an idea, a mental conception. He conducts studies and, when necessary, research into the feasibility of this idea. He directs the building and operation of what he has planned" (18).

Although engineers perform many tasks independently, most products result from team effort, requiring engineers to share their knowledge and the result of their work with others (Holmfeld 156). For complex products, teamwork is required at each stage of the engineering process. The literature on concurrent engineering indicates that teamwork is a natural requirement of the need to integrate the various stages of the engineering process (see Stoll 86, for example). For example bringing a high-quality product to market in an efficient manner often requires that design engineers communicate with managers,

manufacturing, and marketing staff within their firm as well as with people outside their organizations, such as clients, funders, and suppliers.

Engineering work takes place in a variety of environments, depending not only on the nature of the product being developed and the stage of product development, but also on the type of employing organization. Organizations employing engineers include universities, research centers, government laboratories and agencies, and private sector manufacturers and consulting firms. The basic goal of engineering is to produce usable products in the shortest possible time at the lowest possible cost. This goal drives the work and communication activities of virtually all engineers, but it is manifested to a different degree in different employment settings.

Engineering Knowledge

What kinds of knowledge do engineers need to perform the tasks and activities described above? How is knowledge acquired? Engineering work and knowledge are so closely intertwined, that it is difficult to discuss one without the other. As noted by Vincenti, "... engineering knowledge cannot -- and should not -- be separated from engineering practice. The nature of engineering knowledge, the process of its generation, and the engineering activity it serves form an inseparable whole" (257). Engineering practice, in other words, involves both knowing and doing. Even the popular literature suggests the wide variety of knowledge needed by engineers, due to the diversity of their work:

> [The engineer's] task is not alone that of contrivance with material things, for which he must possess an extensive working knowledge of scientific principles and facts. He must also thoroughly understand the functions to be performed by the projected work when it is completed, the methods of its manufacture and construction, and the economics that govern its use. He must have an understanding of the crafts that are to be used and of the organization of the work. It is his responsibility to coordinate and guide the contributions of labor, machines, money, and ideas, and to exert the control necessary to attain his objectives within the prescribed limits of time, cost, and safety. (Hollister 18)

Scholarly literature on the nature and generation of engineering knowledge reinforces such popular accounts. Donovan asserts that the range of scientific and technical knowledge used by engineers includes "not only the more formal types of experimental and theoretical knowledge but also all forms of practical skill and tacit understanding as well . . ." (678).

Schön rejects the model of technical rationality which is typically applied to scientific and technical professions and instead paints a different picture of engineering knowledge. He argues that the situations encountered by practicing professionals are increasingly characterized by "complexity, uncertainty, instability, uniqueness, and value conflicts" (14); such situations require intuitive, artistic, and ethical responses in addition to purely technical and rational ones. Schön labels this model of professional work "tacit knowing-in-action" (49) and describes the development of a new process to produce a desired gunmetal color to illustrate his argument. He represents the activities of the mechanical engineers involved in this project as "a reflective conversation with the materials of the situation . . . [that] wove its way through stages of diagnosis, experiment, pilot process, and production design" (175). Throughout this process, experiments are used to explore puzzling phenomena, test the applicability of potentially useful theories, or achieve particular technological effects. These experiments, however, often produce unanticipated phenomena and outcomes, which then trigger new hypotheses, questions, and goals (177). Schön's analysis of this and other examples suggests that the knowledge required to reach a technological solution is derived from the integration of intuition, past experience, creativity (often in the form of analogy development), theory, experimentation, and reflective thinking that occur in a particular problematic situation. He also argues that engineering solutions incorporate social and ethical considerations.

As these accounts suggest, the notion of tacit knowledge permeates discussions of engineering work. Tacit knowledge is knowledge that cannot be articulated. Polanyi describes tacit knowledge -- part experience, part intuition, part tactile sensation -- as combining "knowing what" and "knowing how" and declares that it is expressed in such

actions as expert diagnoses, the performance of skills, and the use of tools (6-7). Another important type of engineering knowledge, visual information, is also expressed in a nonverbal manner. The importance of visual information in technological work is the subject of a paper by Ferguson and is also discussed by Breton (1991). Layton describes this phenomenon, too: "technologists display a plastic, geometrical, and to some extent nonverbal mode of thought that has more in common with that of artists than that of philosophers" (37). The importance of these two nonverbal modes of thought is rooted in the essence of engineering as the production of physically encoded knowledge. Engineers must know how to make things, and the results of this knowledge are, first and foremost, encoded in the technologies produced. Engineers rely heavily on nontextual information, such as interpersonal communication, drawings, and the examination of physical objects, to acquire the knowledge they need to perform their work.

Research from sociological, historical, communications, and management perspectives has shed light on the nature of engineering knowledge and communication. Several studies offer a close examination of the development of individual technologies. Holmfeld produced a sociological study of the communication behavior of 70 scientists and engineers working on the problem of combustion instability in liquid propellant rocket engines. He found that "technological knowledge is based to a high degree on intuition grounded in extensive individual experience" (121). Many of the engineers interviewed emphasized that an important aspect of engineering knowledge resided in the "feel" that one has for the objects of work. Holmfeld concluded that part of this feel is implicit (i.e., tacit), existing only in the mind and hands of the individual (127). The rest, however, was made explicit and resided in local records of test results, design variations, and other kinds of data. The content of this knowledge includes calculations based on empirical work, widely agreed upon rules of thumb and practice, and the vague statements that are used to try to express the tacit knowledge embodied in having a good feel for one's work.

Holmfeld found three common mechanisms for generating needed knowledge in engineering work. Engineers rely on the "cut and try" method to refine and fine tune (129). They also frequently search their memories for familiar concepts and designs in order to increase their confidence in some new variation (134-135). Finally, they make use of that scientific knowledge which they deem to be relevant and readily applicable. This knowledge is often in the form of a simple fact, such as the optimum hole size or speed rotation, resulting from scientific work (148). A number of other writers also note that engineers adopt, at times, the methods used by scientists to generate knowledge. Florman describes engineering work as encompassing both theory and empiricism (64). Ziman writes that "technological development itself has become 'scientific': it is no longer satisfactory, in the design of a new automobile, say, to rely on rule of thumb, cut and fit, or simple trial and error. Data are collected, phenomena are observed, hypotheses are proposed, and theories are tested in the true spirit of the hypothetico-deductive method." (130)

Constant presents a detailed history of the origin of the modern jet engine, a revolutionary technological advance. He presents a "variation-retention" model of technological change that is based on the process of random variation and selective retention that occurs in biological organisms. Technological conjecture, which can occur as a result of knowledge gained from either scientific theory or engineering practice, yields potential variations to existing technologies. These variations are subsequently tested, and successful variations are retained (1980, 6-7). In the case of the turbojet revolution, technological conjecture was based on engineers' knowledge of scientific theories. The design, development, and testing of systems that resulted in the retention of the most successful variation involved, on the other hand, the technical and craft knowledge needed to carry out those tasks.

Vincenti traces five "normal" (as opposed to revolutionary) developments in the history of aerospace engineering to detail what he calls "the anatomy of engineering design knowledge" (9). His examples reveal that technological developments require a range of scientific, technical, and practical knowledge as well as information about social, economic, military,

and environmental issues. Vincenti conducts three important analyses of engineering knowledge. The first involves his own elaboration of the variation-selection model of the growth of technological knowledge. Vincenti concludes, after examining numerous examples from history, that the mechanisms for producing variations in engineering design include three types of cognitive activities (246): searching past experience to find knowledge that has proved useful, including the identification of variations that have not worked; incorporating novel features thought to have some chance of working; and "winnowing" the conceived variations to choose those most likely to work. Vincenti notes that these activities occur in an interactive and disorderly fashion. Selection occurs through physical trials such as everyday use, experiments, simulations (e.g., the use of wind tunnels), or analytical tests such as the production of sketches of proposed designs, calculations, and other means of imagining the outcome of selecting a proposed variation (247-248).

Vincenti also proposes a schema for engineering knowledge that categorizes knowledge as either descriptive (factual knowledge), prescriptive (knowledge of the desired end), or tacit (knowledge that cannot be expressed in words or pictures but is embodied in judgment and skills). Descriptive and prescriptive knowledge are explicit; tacit knowledge is implicit. Both tacit and prescriptive knowledge are procedural and reflect a "knowing how" (197-198). Finally, Vincenti enumerates and defines specific engineering knowledge categories: fundamental design concepts, criteria and specifications, theoretical tools (i.e., mathematical methods and theories and intellectual concepts), quantitative data, practical considerations, and design instrumentalities (i.e., procedural knowledge and judgmental skills) (208-222). He then presents a matrix that details how each type of knowledge is acquired. The possible sources of engineering knowledge that he describes include transfer from science or generation by engineers during invention, theoretical and experimental engineering research, design practice, production, or direct trial and operation (235).

Communications and management studies confirm the findings of historical and sociological research about the range of knowledge, information, and data needed in engineering

work. Ancona and Caldwell investigated the tasks and communication of new product development teams in high technology companies. The authors note that such teams "are responsible not only for the specific technical design of a product, but also for coordinating the numerous functional areas and hierarchical levels that have information and resources necessary to make the new product a success" (174). Ancona and Caldwell found that new product teams progress through three phases of activity: creation, development, and diffusion. The communication- and information-intensive tasks that accompany these phases include (184-185):

- Getting to know and trust team members
- Determining the availability of resources
- Understanding what other functional groups think the product can/should be
- Investigating technologies for building the product
- Exploring potential markets
- Solving technical problems
- Coordinating the teams' work internally and externally
- Keeping external groups informed
- Building relationships with external groups that will receive the teams' output
- Promoting the product with manufacturing, marketing, and service groups.

Ancona and Caldwell conclude that information systems designed to support these changing activities must be flexible and support the team's need to identify and contact relevant external groups, generate and evaluate ideas, and coordinate work. Barczak and Wilemon also look at the communication patterns of new product development teams and find a similar range of communication purposes: to discuss product features, technical issues, customer needs, manufacturing issues, schedules and timing, financial issues, managerial issues, and resource issues (101-109).

Computer Use in Engineering

Computer networks are playing an increasingly important role in engineering work because they link design and analysis tools with other important resources to create integrated engineering information systems (EIS's) that can be used by engineers from their own desktops. Dirr and Stockdale describe 3M's transition from the use of CAD systems to a distributed computing strategy in which "[a]ll authorized users would have access to information anywhere in the network, and CAD and project management would be joined in a single integrated system" (50). Heiler and Rosenthal define an EIS as the combination of "software tools, data base managers, data bases and hardware to provide integrated environments for engineering design and management" (431). They also describe the rationale for such systems:

> Engineering environments can be extremely complex. They must support long, complex, and interdependent tasks that produce and manipulate highly specialized data. Often multiple representations of the same information are required to support different tasks. Moreover, more than one engineer may work concurrently on different aspects of the same design, which may introduce inconsistencies into the data. (431)

The use of computers and networks to automate the manufacturing process is becoming more widespread. Boll describes the role of the manufacturing automation protocol (MAP) in accomplishing the integration of the manufacturing process: "machining, assembly, warehousing, quality assurance, packaging and dispatch." Schatz describes the increase in computer-integrated manufacturing (CIM) investments worldwide, noting that they are expected to double between 1988 and 1992, reaching about $91 billion.

Electronic data interchange (EDI) is used to exchange orders and invoices with vendors and suppliers, and contracts with clients and customers (Beckett; Purton). Thus, networks are also used in engineering environments to facilitate formal business communication outside the firm. Networks are used in some firms for information retrieval (IR) in connection with both in-house and commercial databases. Information retrieval systems have received mixed reviews from engineers. Christiansen discusses the results of an informal IEEE survey on how engineers obtain the information they need to do their jobs. He reports that engineers have

difficulty performing online searches and often obtain inadequate results. He also interprets the tendency of engineers to "scan and save" large amounts of material as a response to their dislike of retrieval systems (21). Breton presents a more compelling argument for the underutilization of information retrieval systems (1981; 1991). He concludes that the informal and visual material that is important to engineers is not included in most IR systems and, further, that current indexing techniques fail to retrieve information according to those dimensions, such as "desired function," that are useful to engineers. Gould and Pearce describe the results of an assessment, based largely on interviews, intended to relate information needs in engineering to current systems for storing, organizing, and disseminating that information. Mailloux reviews current literature on EIS. She provides an overview of a variety of engineering systems and devotes considerable attention to a discussion of how EIS's support engineering work and communication behavior.

Finally, the literature suggests that engineers also use electronic networks for a variety of interpersonal communication purposes. Borchardt includes electronic mail among his suggestions for improving in-house technical communication in order to facilitate the sharing of ideas, provide a more stimulating work environment, and prevent the duplication of efforts (135). Beckert notes that engineers can use electronic mail to send text, data, and graphics to their colleagues and to automate the notification status change process between engineering, manufacturing, and external entities. She notes that electronic communication eliminates telephone tag and problems associated with time-zone differences, and also saves time in scheduling meetings and responding to technical questions (68). Mishkoff describes computer conferencing as the answer to the problems corporations face when they employ geographically-dispersed work groups. He reports that Hewlett-Packard employs thousands of engineers in over 70 divisions, one-third of which are located outside the United States. Mishkoff describes how computer conferencing is used in place of more expensive mechanisms to allow groups of engineers to share their knowledge efficiently and coordinate their work (29).

The power of computer conferencing systems to form the base of "electronic expert networks in organizations is described by Stevens, although he does not focus exclusively on engineers. His discussion applies the assertions about the importance of informal communication in organizations to the electronic environment. He argues that electronic networks are an important source of expertise for employees because "[t]he best answers frequently come from surprising sources. An unknown peer with relevant experience can sometimes provide better help than a more famous expert, who may be less accessible or less articulate" (360). Stevens also notes that "[w]hile expert networks can be used by traditional organizations to strengthen their effort to produce and provide products and services, expert networks also seem to represent almost a new form of organization" (369).

Many organizations hope that by facilitating communication and improving coordination, electronic networks will decrease both the costs and the time needed by bringing products to market. Due to proprietary and security concerns, a number of engineering organizations have implemented their own private, high-speed networks that are used only by their own employees. The need for high-bandwidth, completely reliable electronic transfer of critical data also makes the use of most public commercial networks infeasible for some industries and applications. Werner and Bremer note that even companies involved in industry-academia-government R&D cooperatives prohibit electronic links to external consortium members for fear of security leaks (46).

The National Research Council's Panel on Engineering Employment Characteristics (National Research Council 1985) conducted an informal survey of engineering employers in which they obtained employers' views on the impact of new tools on engineering productivity. Survey results indicated that about one-third of employers had widely available computer-aided drafting or design systems in place, few had computer-aided manufacturing systems, and about 50 percent had engineering information systems. Fewer than one half of the respondents had formally evaluated their systems although they estimated productivity gains of about 100 percent for drafting systems, 50 percent for design systems, and 35 percent for

information systems (68). The Panel concluded that "these new computer-aided tools permit increasingly sophisticated products to be designed in less time with substantially greater accuracy and with greater cost-effectiveness" (27) although they also noted that "their net effect on engineering and on industry as a whole cannot be forecast with confidence (26).

Computer Use in Aerospace

The aerospace industry possesses a number of characteristics that make it a natural environment for the use of information technology. It is a high technology industry, already highly computerized. It involves significant R&D, which is a communication-intensive activity. Further, its end products are highly complex, calling for a great deal of work task coordination and the integration of information created by diverse people. In describing the business and technology strategy in place at British Aerospace, Hall emphasized the need for increased computing and communications capabilities in aerospace firms aiming to design, develop, make and market complex systems while maintaining a technical competitive edge, and reducing costs (16-2). He noted that a number of typical information technology opportunities were particularly relevant to the aerospace industry, such as "improved productivity, better competitive edge, reduced time scales, closer collaboration, more streamlined management, better commonality of standards across sites, more operational flexibility, [and] constructive change of work force skill levels" (16-2).

Rachowitz et al. describe efforts at Grumman Aerospace to realize a fully distributed computing environment. Grumman's goal is to implement a system of networked workstations in order to "cost-effectively optimize the computing tools available to the engineers, while promoting the systematic implementation of concurrent engineering among project teams" (38). The network includes PC's and software to be used for communication. Grumman assumes that their computer/information integrated environment (CIE) will result in

"product optimization quality products manufactured with fewer errors in shorter time and at a lower cost" (66).

Black presents a brief overview of the uses and advantages of computer conferencing systems, noting that computer conferencing is a "very powerful tool for the transfer of information in all areas of research and development and "a natural for the AGARD community" (13-4). Molholm describes the application of the Department of Defense Computer-aided Acquisition and Logistics Support (CALS) initiative to the aerospace community. CALS mandates the use of specific standards for the electronic creation and transmission of technical information associated with weapons systems development. Eventually all Department of Defense contractors and subcontractors will be required to create and distribute in digital form all the drawings, specifications, technical data, documents, and support information required over the entire life cycle of a military project. The CALS system may be a significant impetus to networking for aerospace firms.

The literature reveals that a number of engineering organizations are using electronic networks for a variety of communication activities, distributed computing, and shared access to information resources. Networks are being implemented to serve organizational goals and business strategies, i.e., to achieve impacts in terms of better and faster product development and cost savings. Such motivations for network investments suggest factors that may encourage network use in particular engineering organizations and alleviate the need for them in others. The literature also hints at a number of factors that may hinder network use, such as security and proprietary concerns, the failure of indexing techniques to retrieve stored information in a way useful to engineers, and the substantial financial outlays required to implement networked systems.

Descriptions of computer and information technology needs, uses, problems, and impacts in engineering environments are scarce. Furthermore, the literature is fragmentary and anecdotal, with few empirical studies having been reported in the literature. Shuchman conducted a broad-based investigation of information transfer in engineering. The respondents

represented 14 industries in the following major engineering disciplines: aeronautical. chemical and environmental, civil, electrical, industrial, and mechanical. As part of this study, Shuchman examined the use of computer and information technology by engineers to "identify the attitudes [of engineers] toward and use patterns of computer and information technology in an effort to forecast the potential value of new information technologies" (36). Overall the survey results indicated that computer and information technology has high potential usefulness but relatively low use among engineers. In analyzing this finding, it is important to keep in mind that the state of the art in computer and information technology has changed dramatically since Shuchman's study was released.

In Shuchman's study, respondents were asked to indicate the use, non-use, and potential use of 21 computer and information technologies categorized into four groups. Overall, aeronautical engineers made greater use of computer and information technologies than did the other respondents. Aeronautical engineers also reported the highest use of "information transmission technologies" (fax, telex, teleconferencing, and video conferencing). They also had the highest use rate for what Shuchman identified as "recorded/pre-recorded information technologies." Of the emerging technologies (e.g., digital imaging), aeronautical engineers reported the highest rate of current use and predicted use.

A pilot study conducted as part of Phase 1 of the NASA/DoD Aerospace Knowledge Diffusion Research Project investigated the technical communications habits and practices of U.S. aerospace engineers and scientists (Pinelli et al., 1989). One of the objectives of this study was to determine the use and importance of computer and information technology to them. Approximately 91 percent of the respondents reported using computer and information technology to communicate STI. Approximately 95 percent of those respondents who reported using this technology indicated that it had increased their ability to communicate. The lowest rates of use for any technology were those reported for the mature technologies (e.g., micrographics). The rate of use for maturing technologies (e.g., electronic data bases) was relatively high, approximately 60 percent. Overall, 50–60 percent of the respon-

dents predicted that they would use the nascent or emerging technologies (e.g., electronic networks) (72-73).

PRESENTATION OF THE DATA

The responses to the survey are presented for four survey topics. The responses are based on 430 completed responses.

Demographics

Survey data demographics for the study appear in table 1. The following "composite" participant profile was based on these data. The survey participant works in industry (85.6%), has a bachelor's and a master's degree (85.6%), was trained as an engineer (87.7%), and works in process or product development (62.8%).

Nature of the Work

About 77 percent (333) of the respondents described their current work activities as aerospace-related, and about 13 percent (55) described their current work activities as non-aerospace-related. About 10 percent (42) of the respondents were retired. Of those performing aerospace related work, about 66 percent (220) considered themselves to be engineers (about 2 percent, or 5 respondents, considered themselves to be scientists) and about 24 percent (79) classified themselves as managers. Of those performing non-aerospace related work, about 58 percent (32) of the respondents classified themselves as engineers, about 2 percent (1) as scientists, about 22 percent (12) as managers, and 18 percent (10) as other.

For both groups (respondents performing aerospace and non-aerospace related work) a majority were trained as engineers. For those performing aerospace-related work, about 88 percent (291) were trained as engineers, 6 percent (19) as scientists, and 6 percent (22) as something else. For those performing non-aerospace-related work, about 84 percent (46) were trained as engineers, 2 percent (1) as scientists, and 14 percent (8) as something else. Of those

Table 1. Survey Demographics

[n = 430]

Demographics	Number	%
Do you currently work in:		
Industry	332	85.6
Government	45	11.6
Academics	1	0.2
Other	10	2.6
Your highest level of education:		
No degree	21	4.9
Technical/Vocational degree	17	4.0
Bachelor's degree	218	50.7
Master's degree	150	34.9
Doctorate	15	3.4
Post Doctorate	1	0.2
Other type of degree	8	1.9
Your years in aerospace:		
0–9	80	23.8
10–19	80	21.4
20–29	73	19.4
30–39	103	27.4
40–>	30	8.0
Were you trained as:		
Aerospace (non-aerospace)		
Engineer	291 (46)	87.7 (83.6)
Scientist	19 (1)	5.7 (1.8)
Other	22 (8)	6.6 (14.6)
Is your work best classified as:		
Basic research	3	1.0
Applied research	37	13.0
Process or product development	179	62.8
Manufacturing	32	11.2
Production	9	3.2
Service or maintenance	5	1.8
Sales or marketing	1	0.3
Something else	19	6.7

who classified themselves as engineers, about two-thirds (190) had spent at least 51 percent of the previous week performing engineering-related activities.

Information-Seeking In the Workplace

Respondents were asked some questions about the sources of information they use at work. The questions and responses appear in table 2. The intent was to see if

Table 2. Information Source Selection

[n = 440]

	Employed in aerospace, %	Not employed in aerospace, %
When you perform your job, co-workers in your place of employment are more important sources of information to you than are outside sources of information.		
Strongly agree	36.8	40.0
Somewhat agree	42.1	34.5
Somewhat disagree	15.1	25.5
Strongly disagree	6.0	0.0
Your preferred method for obtaining technical information is to communicate with co-workers in your place of employment.		
Strongly agree	33.3	21.8
Somewhat agree	47.3	54.4
Somewhat disagree	15.3	20.0
Strongly disagree	4.0	3.6
In general, would you say your primary reason for using co-workers to obtain technical information is:		
Because they are accessible	13.3	16.7
Because the information they have is relevant to your job	49.8	59.5
Because the information they have is of high technical quality	17.1	14.3
A combination of above	19.8	9.5

there were differences in the style that engineers use to gather the information they need on the job. Most respondents indicated that co-workers are important information sources, more so than outside resources.

There were some differences between aerospace and non-aerospace engineers. All engineers in the study prefer co-workers as a source of information over other sources. About 10% more aerospace engineers than non-aerospace engineers strongly agreed that they preferred co-workers as information sources. Nearly 60 percent of the non-aerospace engineers versus 50 percent of the aerospace engineers said relevance of information was the reason they relied on co-workers. Most of those who mentioned a combination of factors said that all three reasons contributed to their use of co-workers as information sources.

Respondents were asked how the technical uncertainty of a project affected the need for information. The questions and responses appear in table 3. Most aerospace engineers (71 percent) agreed that uncertainty increased the need for information. Only 58 percent strongly agreed that uncertainty increased the need for internal information and 42 percent strongly agreed that it increased the need for external information. Non-aerospace engineers also agreed that technical uncertainty increased the need for technical information (66 percent). Only 40 percent strongly agreed that uncertainty increased the need for internal information, and 36 percent strongly agreed that it increased the need for external information.

Use of Electronic Networks

Respondents were asked a series of questions about their use of electronic networks. The questions related to (1) the types of network(s) available and used, (2) the frequency of use of particular network functions, (3) types of communication partners, and (4) the nature of electronic communication.

Table 3. Technical Uncertainty and Information Use

[n = 440]

	Employed in aerospace, %	Not employed in aerospace, %
As the technical uncertainty associated with a problem or project increases, so does the need for technical information. Do you:		
Strongly agree	70.6	65.5
Somewhat agree	27.3	32.7
Somewhat disagree	1.5	1.8
Strongly disagree	0.6	0.0
As the technical uncertainty associated with a problem or project increases, so does the need for technical information internal to the organization.		
Strongly agree	57.5	40.0
Somewhat agree	36.1	52.7
Somewhat disagree	5.7	7.3
Strongly disagree	0.6	0.0
As the technical uncertainty associated with a problem or project increases, so does the need for technical information external to the organization		
Strongly agree	41.7	36.4
Somewhat agree	49.2	49.1
Somewhat disagree	8.5	14.5
Strongly disagree	0.6	0.0

In general, survey results paint a picture of the widespread use of electronic networks within the aerospace community, with relatively little variation among the broad types of work. A majority of respondents (83% overall) reported that networks were accessible to them in the workplace. Further, a majority (71% overall) indicated that they used an electronic network that allowed them to contact people at remote sites, i.e., across town or around the world. Forty-four percent of respondents indicated that they used electronic

networks on a daily basis, and only 7% reported that they never used networks. The remainder of the responses were fairly evenly distributed between perceived use of "once a month or less," "several times a month," and "several times a week." Fewer "engineers" reported daily use than did people in the other job categories. Overall, the most common response (32%) was that networks were used during 10–24% of the past work week, but the data suggest that "engineers" are much more intensive users of networks than are "managers."

Close to 80% of the respondents reported using electronic mail, file transfer, and information or data retrieval related to commercial or in-house data bases. Overall, about 50% used one-to-many electronic communication mechanisms, such as bulletin boards, newsletters or conferencing systems, and 55% used networks for remote log-in to other computer systems. Only 16% reported using electronic networks for the remote control of experimental or manufacturing devices. Thus, the use of networks in engineering work, broadly defined, seems primarily devoted to communication activities, exchanges of data, designs, etc., and distributed computing. There appears to be some variation in network use by the type of work, with "engineers" reporting the least extensive use of networks for one-to-many communications (46%).

Other survey questions further explored the nature of network communcation. About two thirds of the respondents reported that they communicated electronically with people in their work group or others in their organization, while fully half responded that they used networks to communicate with people outside their own organization. Engineers were most likely to use networks to communicate with work group members, but least likely to use networks to communicate with people outside their own organization. Finally, respondents were asked to recall and report the purpose of a recent electronic exchange. A majority of reported exchanges were related to what was termed "technical" communication, including such things as sending data, asking technical questions, receiving specifications, and solving technical problems. Somewhat fewer examples of "administrative" communication were

noted, and substantially fewer respondents reported a recent exchange as being what might be termed either "general" or "social" in nature.

CONCLUDING REMARKS

The SAE telephone survey was undertaken to obtain information on the daily work activities of aerospace engineers and scientists, to measure various practices used by aerospace engineers and scientists to obtain STI, and to ask aerospace engineers and scientists about their use of electronic networks. A majority of respondents were trained as engineers and performed aerospace-related work. Overall, the respondents (strongly or somewhat) agreed that the primary a goal of most engineers in aerospace is to develop or improve a product or process (98%), the primary goal of most scientists in aerospace is to generate and publish new information (69%), and their job requires them to publish new ideas or make original contributions to the literature (36%).

Co-workers are important sources of information to respondents performing both aerospace- and non-aerospace-related work. Respondents performing both aerospace and non-aerospace-related work prefer to obtain needed information from co-workers in their place of employment. A majority of respondents in both groups prefer to use co-workers to obtain needed information because they have information that is relevant to their jobs.

A majority of respondents in both groups (71%/66%) strongly agreed that as the technical uncertainty associated with a problem or project increases, so does the need for technical information. A majority of both groups strongly agreed (58%/40%) that as technical uncertainty increases so, too, does the need for information internal to the organization. A lesser percentage of the respondents in both groups (42%/36%) strongly agreed that as technical uncertainty increases so, too, does the need for information external to the organization.

Popular and scholarly literatures have addressed the nature of engineering work, the nature and role of communication in science and technology and, increasingly, the characteristics

and effects of electronic communication in various communities. Few studies have appeared that examine networking in engineering.

Networks appear to be used quite widely for both internal and external communication purposes by engineers in the aerospace industry, especially for technical and administrative exchanges. Although electronic communication is perceived to contribute to engineering efficiency and effectiveness, its use is limited (at least in terms of today's technology) by an engineer's need for immediate, highly interactive discussion of complex problems of both a technical and non-technical nature. Networks do not provide an adequate means to convey the multi-faceted, multimedia information that is typically exchanged in those situations where, for example, engineers discuss issues and solutions while simultaneously consulting drawings, contracts, financial data, test results, and physical devices. Use also appears to be limited by an organization's lack of experience with electronic communcation: while dangers are easy to imagine and costs easy to tally, benefits are hard to predict and quantify.

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APPENDIX A

NASA/DoD AEROSPACE KNOWLEDGE DIFFUSION RESEARCH PROJECT

Fact Sheet

The production, transfer, and use of scientific and technical information (STI) is an essential part of aerospace R&D. We define STI production, transfer, and use as *Aerospace Knowledge Diffusion*. Studies tell us that timely access to STI can increase productivity and innovation and help aerospace engineers and scientists maintain and improve their professional skills. These same studies remind us that we know little about aerospace knowledge diffusion or about how aerospace engineers and scientists find and use STI. To learn more about this process, we have organized a research project to study knowledge diffusion. Sponsored by NASA and the Department of Defense (DoD), the NASA/DoD Aerospace Knowledge Diffusion Research Project is being conducted by researchers at the NASA Langley Research Center, the Indiana University Center for Survey Research, and Rensselaer Polytechnic Institute. This research is endorsed by several aerospace professional societies including the AIAA, RAeS, and DGLR and has been sanctioned by the AGARD and AIAA Technical Information Panels.

This 4-phase project is providing descriptive and analytical data regarding the flow of STI at the individual, organizational, national, and international levels. It is examining both the channels used to communicate STI and the social system of the aerospace knowledge diffusion process. Phases 1 investigates the information-seeking habits and practices of U.S. aerospace engineers and scientists and places particular emphasis on their use of government funded aerospace STI. Phase 2 examines the industry-government interface and places special emphasis on the role of the information intermediary in the knowledge diffusion process. Phase 3 concerns the academic-government interface and places specific emphasis on the information intermediary-faculty-student interface. Phase 4 explores the information-seeking behavior of non-U.S. aerospace engineers and scientists from Brazil, Western Europe, India, Israel, Japan, and the Soviet Union.

The results will help us to understand the flow of STI at the individual, organizational, national, and international levels. The results of our research will contribute to increasing productivity and to improving and maintaining the professional competence of aerospace engineers and scientists. They can be used to identify and correct deficiencies, to improve access and use, to plan new aerospace STI systems, and should provide useful information to R&D managers, information managers, and others concerned with improving access to and utilization of STI. The results of our research are being shared freely with those who participate in the study. We have presented our findings at international meetings and have published several papers. You can get copies by contacting Dr. Pinelli.

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APPENDIX B

NASA/DoD AEROSPACE KNOWLEDGE DIFFUSION RESEARCH PROJECT PUBLICATIONS

REPORTS

<u>Report No.</u>

Report No.	
1 PART 1	Pinelli, Thomas E.; Myron Glassman; Walter E. Oliu; and Rebecca O. Barclay. **Technical Communications in Aerospace: Results of Phase 1 Pilot Study.** Washington, DC: National Aeronautics and Space Administration. NASA TM-101534. February 1989. 106 p. (Available from NTIS 89N26772.)
1 PART 2	Pinelli, Thomas E.; Myron Glassman; Walter E. Oliu; and Rebecca O. Barclay. **Technical Communications in Aerospace: Results of a Phase 1 Pilot Study.** Washington, DC: National Aeronautics and Space Administration. NASA TM-101534. February 1989. 83 p. (Available from NTIS 89N26773.)
2	Pinelli, Thomas E.; Myron Glassman; Walter E. Oliu; and Rebecca O. Barclay. **Technical Communication in Aerospace: Results of Phase 1 Pilot Study -- An Analysis of Managers' and Nonmanagers' Responses.** Washington, DC: National Aeronautics and Space Administration. NASA TM-101625. August 1989. 58 p. (Available from NTIS 90N11647.)
3	Pinelli, Thomas E.; Myron Glassman; Walter E. Oliu; and Rebecca O. Barclay. **Technical Communication in Aerospace: Results of Phase 1 Pilot Study -- An Analysis of Profit Managers' and Nonprofit Managers' Responses.** Washington, DC: National Aeronautics and Space Administration. NASA TM-101626. October 1989. 71 p. (Available from NTIS 90N15848.)
4	Pinelli, Thomas E.; John M. Kennedy; and Terry F. White. **Summary Report to Phase 1 Respondents.** Washington, DC: National Aeronautics and Space Administration. NASA TM-102772. January 1991. 8 p. (Available from NTIS 91N17835.)
5	Pinelli, Thomas E.; John M. Kennedy; and Terry F. White. **Summary Report to Phase 1 Respondents Including Frequency Distributions.** Washington, DC: National Aeronautics and Space Administration. NASA TM-102773. January 1991. 53 p. (Available from NTIS 91N20988.)
6	Pinelli, Thomas E. **The Relationship Between the Use of U.S. Government Technical Reports by U.S. Aerospace Engineers and Scientists and Selected Institutional and Sociometric Variables.** Washington, DC: National Aeronautics and Space Administration. NASA TM-102774. January 1991. 350 p. (Available from NTIS 91N18898.)

7 Pinelli, Thomas E.; John M. Kennedy; and Terry F. White. **Summary Report to Phase 2 Respondents Including Frequency Distributions.** Washington, DC: National Aeronautics and Space Administration. NASA TM-104063. March 1991. 42 p. (Available from NTIS 91N22931.)

8 Pinelli, Thomas E.; John M. Kennedy; and Terry F. White. **Summary Report to Phase 3 Faculty and Student Respondents.** Washington, DC: National Aeronautics and Space Administration. NASA TM-104085. June 1991. 8 p. (Available from NTIS 91N24943.)

9 Pinelli, Thomas E.; John M. Kennedy; and Terry F. White. **Summary Report to Phase 3 Faculty and Student Respondents Including Frequency Distributions.** Washington, DC: National Aeronautics and Space Administration. NASA TM-104086. June 1991. 42 p. (Available from NTIS 91N25950.)

10 Pinelli, Thomas E.; John M. Kennedy; and Terry F. White. **Summary Report to Phase 3 Academic Library Respondents Including Frequency Distributions.** Washington, DC: National Aeronautics and Space Administration. NASA TM-104095. August 1991. 42 p. (Available from NTIS 91N33013.)

11 Pinelli, Thomas E.; Madeline Henderson; Ann P. Bishop; and Philip Doty. **Chronology of Selected Literature, Reports, Policy Instruments, and Significant Events Affecting Federal Scientific and Technical Information (STI) in the United States.** Washington, DC: National Aeronautics and Space Administration. NASA TM-101662. January 1992. 130 p. (Available from NTIS 92N17001.)

12 Glassman, Nanci A. and Thomas E. Pinelli. **An Initial Investigation Into the Production and Use of Scientific and Technical Information (STI) at Five NASA Centers: Results of a Telephone Survey.** Washington, DC: National Aeronautics and Space Administration. NASA TM-104173. June 1992. 80 p. (Available from NTIS 92N27170.)

13 Pinelli, Thomas E. and Nanci A. Glassman. **Source Selection and Information Use by U.S. Aerospace Engineers and Scientists: Results of a Telephone Survey.** Washington, DC: National Aeronautics and Space Administration. NASA TM-107658. September 1992. 27 p. (NTIS pending.)

14 Pinelli, Thomas E.; John M. Kennedy; and Terry F. White. **Engineering Work and Information Use in Aerospace: Results of a Telephone Survey.** Washington, DC: National Aeronautics and Space Administration. NASA TM-107673. October 1992. 25 p. (NTIS Pending.)

PAPERS

Paper No.

1 Pinelli, Thomas E.; Myron Glassman; Rebecca O. Barclay; and Walter E. Oliu. **The Value of Scientific and Technical Information (STI), Its Relationship to Research and Development (R&D), and Its Use by U.S. Aerospace Engineers and Scientists.** Paper presented at the European Forum "External Information: A Decision Tool" January 19, 1990, Strasbourg, France. (Available from AIAA 90A21931.)

2 Blados, Walter R.; Thomas E. Pinelli; John M. Kennedy; and Rebecca O. Barclay. **External Information Sources and Aerospace R&D: The Use and Importance of Technical Reports by U.S. Aerospace Engineers and Scientists.** Paper prepared for the 68th AGARD National Delegates Board Meeting, 29 March 1990, Toulouse, France. (Available from NTIS 90N30132.)

3 Kennedy, John M. and Thomas E. Pinelli. **The Impact of a Sponsor Letter on Mail Survey Response Rates.** Paper presented at the Annual Meeting of the American Association for Public Opinion Research, May 1990, Lancaster, PA. (Available from NTIS 92N28112.)

4 Pinelli, Thomas E.; Rebecca O. Barclay; John M. Kennedy; and Myron Glassman. **Technical Communications in Aerospace: An Analysis of the Practices Reported by U.S. and European Aerospace Engineers and Scientists.** Paper presented at the International Professional Communication Conference (IPCC), Post House Hotel, Guilford, England, 14 September 1990. (Available from NTIS 91N14079; and AIAA 91A19799.)

5 Pinelli, Thomas E. and John M. Kennedy. **Aerospace Librarians and Technical Information Specialists as Information Intermediaries: A Report of Phase 2 Activities of the NASA/DoD Aerospace Knowledge Diffusion Research Project.** Paper presented at the Special Libraries Association, Aerospace Division - 81st Annual Conference, Pittsburgh, PA, June 13, 1990. (Available from AIAA 91A19804.)

6 Pinelli, Thomas E. and John M. Kennedy. **Aerospace Knowledge Diffusion in the Academic Community: A Report of Phase 3 Activities of the NASA/DoD Aerospace Knowledge Diffusion Research Project.** Paper presented at the 1990 Annual Conference of the American Society for Engineering Education - Engineering Libraries Division, Toronto, Canada, June 27, 1990. (Available from AIAA 91A19803.)

7 Pinelli, Thomas E. and John M. Kennedy. **The NASA/DoD Aerospace Knowledge Diffusion Research Project: The DoD Perspective.** Paper presented at the Defense Technical Information Center (DTIC) 1990 Annual Users Training Conference, Alexandria, VA, November 1, 1990. (Available from AIAA 91N28033.)

8 Pinelli, Thomas E.; John M. Kennedy; and Rebecca O. Barclay. **The Role of the Information Intermediary in the Diffusion of Aerospace Knowledge.** Reprinted from *Science and Technology Libraries,* Volume 11, No. 2 (Winter), 1990: 59-76. (Available from NTIS 92N28113.)

9 Eveland, J.D. and Thomas E. Pinelli. **Information Intermediaries and the Transfer of Aerospace Scientific and Technical Information (STI): A Report From the Field.** Paper commissioned for presentation at the 1991 NASA STI Annual Conference held at the NASA Marshall Space Flight Center, Huntsville, AL, April 9, 1991. (Available from NTIS 91N21959.)

10 Pinelli, Thomas E.; John M. Kennedy; and Rebecca O. Barclay. **The NASA/DoD Aerospace Knowledge Diffusion Research Project.** Reprinted from *Government Information Quarterly,* Volume 8, No. 2 (1991): 219-233. (Available from AIAA 91A35455.)

11 Pinelli, Thomas E. and John M. Kennedy. **The Voice of the User -- How U.S. Aerospace Engineers and Scientists View DoD Technical Reports.** Paper presented at the 1991 Defense Technical Information Center's (DTIC) Managers Planning Conference, Solomon's Island Holiday Inn, MD, May 1, 1991. (Available from AIAA 91A41123.)

12 Pinelli, Thomas E.; John M. Kennedy; and Rebecca O. Barclay. **The Diffusion of Federally Funded Aerospace Research and Development (R&D) and the Information-Seeking Behavior of U.S. Aerospace Engineers and Scientists.** Paper presented at the Special Libraries Association (SLA) 82nd Annual Conference, San Antonio, TX, June 11, 1991. (Available from AIAA 92A29652.)

13 Pinelli, Thomas E. **The Information-Seeking Habits and Practices of Engineers.** Reprinted from *Science & Technology Libraries,* Volume 11, No. 3, (Spring) 1991: 5-25. (Available from NTIS 92N28114.)

14 Barclay, Rebecca O.; Thomas E. Pinelli; David Elazar; and John M. Kennedy. **An Analysis of the Technical Communications Practices Reported by Israeli and U.S. Aerospace Engineers and Scientists.** Paper presented at the International Professional Communication Conference (IPCC), The Sheraton World Resort, Orlando, FL, November 1, 1991. (Available from NTIS 92N28183.)

15 Barclay, Rebecca O.; Thomas E. Pinelli; Michael L. Keene; John M. Kennedy; and Myron Glassman. **Technical Communications in the International Workplace: Some Implications for Curriculum Development.** Reprinted from *Technical Communication,* Volume 38, No. 3 (Third Quarter, August 1991): 324-335. (Available from NTIS 92N28116.)

1 6 Pinelli, Thomas E.; John M. Kennedy; Rebecca O. Barclay; and Terry F. White. **Aerospace Knowledge Diffusion Research.** Reprinted from *World Aerospace Technology '91: The International Review of Aerospace Design and Development,* Volume 1 (1991): 31-34. (Available from NTIS 92N28220.)

1 7 Pinelli, Thomas E.; Rebecca O. Barclay; John M. Kennedy; Nanci Glassman; and Loren Demerath. **The Relationship Between Seven Variables and the Use of U.S. Government Technical Reports by U.S. Aerospace Engineers and Scientists.** Paper presented at the 54th Annual Meeting of the American Society for Information Science (ASIS), The Washington Hilton & Towers, Washington, DC, October 30, 1991. (Available from NTIS 92N28115.)

1 8 Hernon, Peter and Thomas E. Pinelli. **Scientific and Technical Information (STI) Policy and the Competitive Position of the U.S. Aerospace Industry.** Paper presented at the 30th Aerospace Meeting of the American Institute of Aeronautics and Astronautics (AIAA), Bally's Grand Hotel, Reno, NV, January 1992. (Available from AIAA 92A28233.)

1 9 Pinelli, Thomas E.; John M. Kennedy; Rebecca O. Barclay; and Ann P. Bishop. **Computer and Information Technology and Aerospace Knowledge Diffusion.** Paper presented at the Annual Meeting of the American Association for the Advancement of Science (AAAS), The Hyatt Regency Hotel, Chicago, IL, February 8, 1992. (Available from NTIS 92N28211.)

2 0 Holland, Maurita P.; Thomas E. Pinelli; Rebecca O. Barclay; and John M. Kennedy. **Engineers As Information Processors: A Survey of U.S. Aerospace Engineering Faculty and Students.** Reprinted from the *European Journal of Engineering Education,* Volume 16, No. 4 (1991): 317-336. (Available from NTIS 92N28155.)

2 1 Pinelli, Thomas E.; Rebecca O. Barclay; Maurita P. Holland; Michael L. Keene; and John M. Kennedy. **Technological Innovation and Technical Communications: Their Place in Aerospace Engineering Curricula. A Survey of European, Japanese, and U.S. Aerospace Engineers and Scientists.** Reprinted from the *European Journal of Engineering Education,* Volume 16, No. 4 (1991): 337-351. (Available from NTIS 92N28184.)

2 2 Pinelli, Thomas E. **Establishing a Research Agenda for Scientific and Technical Information (STI): Focus on the User.** Paper presented at the "Research Agenda in Information Science" workshop sponsored by the Advisory Group for Aerospace Research and Development (AGARD), April 7-9 1992, Lisbon, Portugal. (Available from NTIS 92N28117.)

2 3 Pinelli, Thomas E.; Rebecca O. Barclay; Ann P. Bishop; and John M. Kennedy. **Information Technology and Aerospace Knowledge Diffusion: Exploring the Intermediary-End User Interface in a Policy Framework.** Reprinted from *Electronic Networking: Research, Applications and Policy.* 2:2 (Summer 1992): 31-49. (AIAA pending.)

APPENDIX C

SAE TELEPHONE INSTRUMENT

Q1.0 First, I am going to ask a few questions about your current work. Would you describe your current work activities as aerospace-related or would you use some other term to describe them?

1 aerospace-related [goto q2]
5 other term - what is it? [specify]
6 retired (VOLUNTEERED) [go to demr]
8 DK
9 RF
===>[goto q2a]

Q2.0 We understand that people in the aerospace industry, no matter what their job titles, often perform a wide variety of tasks on a day-to-day basis. If you could use only one term to define what you do at work, would you say you are an engineer, a scientist, a manager, or something else?

1 engineer [goto trn1]
3 scientist [goto trn1]
5 manager
7 something else - what term would you use? [specify][goto trn1]
8 DK
9 RF [goto inf1]
===>

Q2.1 Would you consider yourself closer to an engineer or a scientist or [bold]don't[normal] you consider yourself to be either?

1 engineer
3 scientist
5 neither
8 DK
9 RF
===>

Q2.2 Were you trained as an engineer, a scientist, or something else?

1 engineer
3 scientist
5 something else - what was it? [specify]
8 DK
9 RF
===>[goto JT01]

Q3.0 We understand that people, no matter what their job titles, often perform a wide variety of tasks on a day-to-day basis. We'd like to know more about the different kinds of activities you do at work. If you could use only one term to define what you do at work, would you say you are an engineer, a scientist, a manager, or something else?

1 engineer
3 scientist
5 manager
7 something else - what term would you use? [specify]
8 DK
9 RF [goto eng5]
===>

Q3.1 Were you trained as an engineer, a scientist, or something else?

1 engineer
3 scientist
5 something else - what was it? [specify]
8 DK
9 RF
===>[goto eng5]

Q3.2 Could you tell me a few of the activities you did in the last work week that you consider to be engineering? Please feel free to use terms that are easy for you to describe your work activities.

===> [specify]

Q3.3 Please describe a few activities you did in the last work week that you *[bold]don't[normal]* consider to be engineering.

===> [specify]

Q3.4 About what percentage of the last work week did you spend doing activities that you consider to be engineering?

0-100
998 DK
999 RF
===>

Q4.0 I am going to read you some broad classifications that engineers might use to describe their work. Please tell me which [bold]one[normal] of the following classifications best describes your current work. Would you say your work is:

01 basic research
02 applied research
03 process or product development
04 manufacturing or
05 something else? [goto en4a]
98 DK [goto en4a]
99 RF
===>[goto enjo]

Q4.1 Could you classify your current work as:

06 production
07 service or maintenance
08 sales or marketing, or
09 something else [goto en4b]
98 DK
99 RF
===>[goto enjo]

Q4.2 (SPECIFY HERE:)[*no erase*]

===>[specify][goto enjo]

Q4.3 Could you tell me some activities you did in the last work week that you consider to be science-related? Please feel free to use terms that are easy for you to describe your work activities.

===> [specify]

Q4.4 Please describe a few activities you did in the last work week that you [bold]don't[normal] consider to be science-related.

===> [specify]

Q4.5 About what percentage of the last work week did you spend doing activities that you consider to be science-related?

0-100
998 DK
999 RF
===>

Q4.6 I am going to read you some broad classifications that some people use to describe their work. Please tell me which [bold]one[normal] of the following classifications best describes your current work. Would you say your work is:

01 basic research
02 applied research
03 process or product development
04 manufacturing, or
05 something else? [goto sc4a]
98 DK [goto sc4a]
99 RF
===>[goto enjo]

Q4.7 Could you classify your current work as:

06 production
07 service or maintenance
09 sales or marketing, or
97 something else [goto sc4b]
98 DK
99 RF
===>[goto enjo] ===>[specify]

Q5.0 I will now read a series of statements about activities you might do at work. For each statement, please tell me how much you agree or disagree.

Q5.1 First, the primary goal of most engineers in aerospace is [bold]to develop or improve a product or process.[normal] Do you:

1 strongly agree
3 somewhat agree
5 somewhat disagree, or
7 strongly disagree with this statement?
8 DK
9 RF
===>

Q5.2 The primary goal of most scientists in aerospace is [bold]to generate and publish new information.[normal] Do you:

1 strongly agree
3 somewhat agree
5 somewhat disagree, or
7 strongly disagree?
8 DK
9 RF
===>

Q5.3 Your job requires you to publish new ideas or make original contributions to the literature. Do you:

1 strongly agree
3 somewhat agree
5 somewhat disagree, or
7 strongly disagree?
8 DK
9 RF
===>

Q5.4 When you perform your job, co-workers in your place of employment are more important sources of information to you than are outside sources of information. (Do you:)

1 strongly agree
3 somewhat agree
5 somewhat disagree, or
7 strongly disagree

(VOLUNTEERED)

0 I work alone [goto TTT1]
8 DK
9 RF
===>

Q5.5 Your preferred method for obtaining technical information is to communicate with co-workers in your place of employment. (Do you:)

1 strongly agree[goto en5a]
3 somewhat agree[goto en5a]
5 somewhat disagree, or
7 strongly disagree
8 DK
9 RF
===>[goto inf1]

Q6.0 Next, we would like to know about how you obtain technical information while performing your daily work activities. I am going to read you some statements, for each please tell me how much you agree or disagree.

Q6.1 When you perform your job, co-workers in your place of employment are more important sources of information to you than are outside sources of information. (Do you:)

1 strongly agree
3 somewhat agree
5 somewhat disagree, or
7 strongly disagree

(VOLUNTEERED)

0 I work alone [goto TTT1]
8 DK
9 RF
===>

Q6.2 Your preferred method for obtaining technical information is to communicate with co-workers in your place of employment. (Do you:)

1 strongly agree[goto en5a]
3 somewhat agree[goto en5a]
5 somewhat disagree, or
7 strongly disagree
8 DK
9 RF
===>[goto inf1]

Q6.3 In general, would you say your primary reason for using co-workers to obtain technical information is:

1 because they are accessible
2 because the information they have is relevant to your job, or
3 because the information they have is of high technical quality

(VOLUNTEERED)

7 A combination (specify)[specify]
8 DK
9 RF
===>[goto infa]

Q7.0 Next, we would like to know about how you obtain technical information while performing your daily work activities. I am going to read you some statements, for each please tell me how much you agree or disagree.

Type <1> to proceed
===>

Q7.1 As the technical uncertainty associated with a problem or project increases [bold]so does the need for technical information.[normal] Do you:

1 strongly agree
3 somewhat agree
5 somewhat disagree, or
7 strongly disagree with this statement?
8 DK
9 RF
===>

Q7.2 As the technical uncertainty associated with a problem or project increases [bold]so does the need for technical information internal to the organization. [normal] (Do you:)

1 strongly agree
3 somewhat agree
5 somewhat disagree, or
7 strongly disagree
8 DK
9 RF
===>

Q7.3 As the technical uncertainty associated with a problem or project increases [bold]so does the need for technical information external[bold] to the organization. [normal] (Do you:)

1 strongly agree
3 somewhat agree
5 somewhat disagree, or
7 strongly disagree
8 DK
9 RF
===>

Q8.0 The next few questions deal with the use of electronic networks for such things as electronic mail, the control of remote equipment, and on-line information searching. We are interested in how the use of networks affects people's work.

Q8.1 At your workplace, do you have access to electronic networks?

1 yes[goto cmc2]
5 no
8 DK
9 RF
===>[goto dem0]

Q8.2 About how often do you use networks? Would you say:

1 never[goto dem0]
2 once a month or less
3 several times a month
4 several times a week, or
5 daily
8 DK
9 RF [goto dem0]
===>

Q8.3 Do you use a network that allows you to connect to geographically distant sites, which could be across town or around the world?

1 yes
5 no
8 DK
9 RF
===>

Q8.4 Now I'm going to list some functions that networks provide. Please tell me which you use, even if you don't use them often. Do you use electronic mail?

1 yes
5 no
8 DK
9 RF
===>

Q8.5 Do you use electronic bulletin boards or conferences?

1 yes
5 no
8 DK
9 RF
===>

Q8.6 (Do you use) networks for electronic file transfers?

1 yes
5 no
8 DK
9 RF
===>

Q8.7 Do you use networks to log into remote computers for such things as computational analysis or the use of design tools?

1 yes
5 no
8 DK
9 RF
===>

Q8.8 (Do you use networks) to control remote equipment such as laboratory instruments or machine tools?

1 yes
5 no
8 DK
9 RF
===>

Q8.9 (Do you use networks) for information searching or data retrieval?

1 yes
5 no
8 DK
9 RF
===>

Q8.10 Many people use electronic networks to communicate with other people. Do you exchange electronic messages or files with members of your work group?

1 yes
5 no
8 DK
9 RF
===>

Q8.11 Do you exchange electronic messages or files with other people in your organization who are not in your work group?

1 yes
5 no
8 DK
9 RF
===>

Q8.12 Do you exchange electronic messages or files with people outside your organization?

1 yes
5 no
8 DK
9 RF
===>

Q8.13 People can use electronic messages for many purposes, for example, to keep in touch with friends, to schedule meetings, and to ask technical questions, among other things. If you think about the last several messages you sent or received, how would you describe their functions?

===> [specify]

Q8.14 About what percentage of the last work week was spent using networks for any purpose at all?

0-100
998 DK
999 RF
===>[goto dem0]

Q9.0 Although we would like to learn more about your work experience, this project focuses on engineers and scientists who are [bold]currently [normal] working in aerospace. Therefore, I have just a few more questions to ask you that will help us group answers for analysis.

Q9.1 How would you classify the type of organization you are currently working for? Would you say it is:

1 industry
2 government
3 academic
4 not-for-profit, or
5 something else - what would you call it?[specify]
8 DK
9 RF
===>

Q9.2 How many years of professional work experience do you have in aerospace?

0-49 years
50 more than 50 years
98 DK
99 RF
===>

Q9.3 What is the highest level of education that you have completed?

1 technical or vocational degree
2 bachelor's degree
3 master's degree
4 doctorate
5 post doctorate

(VOLUNTEERED)

0 I don't have a degree
6 some other type of degree, specify[specify]
8 DK
9 RF
===>